Addressing Engineering Educators’ Concerns: Collaborative Learning and Achievement

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Abstract - Recent calls for engineering education reform have included collaborative learning as a means to prepare students for future careers in engineering. The purpose of this study was to examine the effects of collaboration and self-efficacy on undergraduate engineering students’ achievement. The results indicated significant positive correlations between collaborative learning and course grade ($r = .29$) and self-efficacy and course grade ($r = .44$). The linear combination of collaboration and self-efficacy accounted for 22% of the variance in course grade. Collaborative learning remained a significant predictor of course grade over and above self-efficacy. The results showed that students engaging in collaboration with peers achieved at higher levels than those who did not. In a field where individual work and competition has traditionally been valued, opportunities for collaboration may be beneficial to students’ academic achievement.

Index Terms - Academic achievement, Collaborative learning, Engineering education, Self-efficacy

THEORETICAL FRAMEWORK

Recent calls for reform in engineering education include collaboration as a means to prepare students for future engineering careers [1]-[4]. In traditional engineering education, student collaboration has not been a preferred method of instruction. Students who pursued careers in engineering learned primarily through instructor lectures, lab experiences, and homework assignments with heavy emphasis on individual work to master vast amounts of scientific knowledge and technological skills [2]. However, professional engineers don’t work in isolation; instead, they must interact with other engineers and professionals to exchange ideas, to give and receive critiques, and to cooperate with others to implement their ideas [3, 4]. Due to this gap between engineering education and professional practice, Kalonji [3] argues that undergraduate students usually lack an accurate vision for the day to day requirements of a future engineering career, and traditional teaching techniques in the engineering sciences do not adequately instill communication, leadership, and teamwork skills for success in future collaborative practice.

Smith & MacGregor [5] describe collaborative learning as “an umbrella term for a variety of educational approaches involving joint intellectual efforts by students, or students and teachers together.” The most popular collaborative learning strategy is team-based design activities where students work together in groups to achieve a particular goal [2]. However, simply putting students in groups doesn’t guarantee improved student learning. The underlying assumption of collaborative learning is that human interactions will encourage learners to actively seek meaning for what they learn and construct knowledge through group participation [6]. The immediate feedback provided by the peer interaction helps students to identify gaps in their understanding through meta-cognitive reflection on their own learning. Prince [2] identified the core element of collaborative learning to be an “emphasis on student interaction rather than on learning as a solitary activity.”

The recognition by researchers that collaboration is a vital skill for future practice and an important factor in undergraduate engineering students’ learning has led to suggested reforms in engineering education [2]. Prince [2] argued for reformulating the structure of undergraduate student’s engineering curriculum. He advocated a new curriculum based on fostering students’ ability to problem solve using team-based collaborative work focused on authentic problems. While large scale reforms in engineering education have made substantive changes to engineering educators thinking about formal instruction [7]-[9], other research has focused on the invention of collaborative tools in various forms and the evaluation of their effectiveness which can be adopted along with the traditional instruction [4, 6, 10].

Recent research using computer based collaborative learning tools [4, 11] has uncovered telling attitudes and beliefs held by engineering students and educators. In these studies, students were asked to exchange their ideas or work cooperatively on an assignment outside of the classroom. Although prior studies have shown that this kind of collaborative learning has a positive effect on student knowledge building and enhances students’ perceptions of collaboration in a regular classroom environment [11], Guzdial et al. [4] found that instructors as well as students in engineering, mathematics, and computer science courses showed active resistance to use of collaborative technology.

The competitive atmosphere in classes graded on a curve in addition to the use of assignments with one perceived right answer was found to impede students’ willingness to collaborate with their classmates. Students
who knew the correct answer believed they should not share answers with classmates for fear they would lose their grade advantage. Slightly different beliefs were noted in those students who didn’t know the correct answer. Guzdial et al. [4] observed that these students experienced learned helplessness [12] when learning in such a competitive and isolated environment. Learned helplessness describes the behavioral pattern in which students give up seeking help or searching for effective learning strategies when they encounter failure. These students are not confident in their abilities, often fear teachers’ harsh criticism, and blame their failure on fixed internal sources (i.e. a lack of intrinsic ability) [4, 12]. If students believe that the primary goal for engineering undergraduates is to compete for the correct answer, they may perceive little need for interaction with their peers (i.e. help-seeking and giving), an important component of the engineering profession.

Despite its lack of widespread acceptance, collaborative learning has been shown to effectively promote students’ achievement on traditional measures [2, 11] and engineering students’ retention in academic programs [13]. In particular, the meta-analysis done by Springer et al. [14] analyzed thirty seven studies of undergraduate students in science, mathematics, engineering, and technology courses and programs. Results demonstrated that various forms of small-group learning effectively increased students’ academic performance, favorable attitudes toward learning, and academic persistence.

Although the effectiveness of collaborative learning has been well documented in the engineering education literature, many of those studies have examined collaborative learning in contrast with traditional classroom instruction. This approach could give those who prefer traditional instruction an impression that student collaboration can only be accomplished through the implementation of collaborative learning tools, time consuming instructional strategies, or virtual forums. However, the core element of collaborative learning is the interaction between the learners, and the opportunity to actively construct knowledge and encode new information through interaction does not inherently require a complete revamping of engineering education. Rather, simple strategies such as giving students a few minutes in class to reflect upon the solution to a problem, or to plan an avenue of problem solving, during a lecture can result in improved retention [2]. Even though undergraduate engineering education has not traditionally encouraged student interaction, recent studies have found student collaboration in engineering classrooms to be positively associated with beneficial outcomes [1][4].

Another well accepted factor that affects student achievement is self-efficacy, or the belief that one can successfully perform the task at hand [15]. Self-efficacy for learning has been shown to be predictive of many types of learning behaviors and outcomes including persistence in the face of failure, adaptive goal setting, self-regulation, and achievement and is often associated with prior experiences in specific learning domains [16]. Specifically, studies have shown that for undergraduate students enrolled in science and engineering courses, high self-efficacy for learning course material influenced their academic persistence, which in turn was necessary to maintain high academic achievement [17].

While self-efficacy and other socio-cognitive psychological measures of the self have become common in engineering educational study, especially in regard to gender and ethnicity [1, 7], collaborative learning stands in sharp contrast to the traditional approaches to engineering education; its benefit in regard to student achievement has been subject to question by educators and researchers alike [2]. The purpose of this study was to examine the combined effects of students’ self-reported collaboration and self-efficacy on their achievement in engineering learning settings. In this investigation, engineering students’ perceptions of collaboration and self-efficacy were measured. Students’ perceptions of collaboration and knowledge building were not dependent upon instructional style used in the course but were based on their perceived experiences. Our research questions were a) What is the relationship between engineering students’ perceptions of collaborative learning, self-efficacy, and academic performance? and b) Do students’ perceptions of collaborative learning predict their academic performance over and above their perceptions of self-efficacy? We hypothesized that students’ perceived collaboration would be significantly associated with both students’ perceived self-efficacy and their engineering course grade, and that students’ perceived collaboration would significantly predict their course grade over and above perceptions of self-efficacy.

**METHOD**

I. Participants

One hundred and fifty students majoring in engineering participated in our study during the spring semester of 2007. Participants were recruited from Mechanical and Aerospace Engineering (MAE) courses at a large southwestern university. Students in our sample were divided between eight courses - two 200 Level courses (n=60); five 300 Level courses (n=74); and one 400 Level course (n=16) - which were taught by different instructors. The participants approximately reflected the ethnic and gender breakdown of the student population. The number of participants from each class was representative of class size in general.

II. Procedures

The collaborative learning subscale of the Student Perceptions of Classroom Knowledge-building (SPOCK) [11] and the self-efficacy subscale of the Motivation Strategies for Learning Questionnaire (MSLQ) [18] were administered to assess students’ perceptions of their collaborative learning and self-efficacy. Students’ final grades for the courses were included in the data set.
The SPOCK is an instrument used to measure students' knowledge building and intentional learning behaviors [11]. The collaborative learning subscale of the SPOCK was used to assess students' perceived collaborative learning behaviors. The students responded on a 5-point Likert-type scale ranging from “almost always” to “almost never.” The collaborative learning subscale did not assess the professors’ instructional strategies but rather students’ perceptions about how they learned classroom material.

The MSLQ is an instrument used to measure motivation and use of learning strategies by college students [18]. The self-efficacy subscale of the MSLQ was used to assess student’s confidence in their ability to learn course material and do well in the course. Student self-efficacy was assessed on a 7-point Likert-type scale ranging from “not at all true” to “very true of me,” and assessed students’ confidence in their ability to learn course material.

III. Measures

- **SPOCK Collaborative Learning.** This subscale assessed students’ perceptions of their interactive learning behaviors with their classmates. There were a total of 5 items used. Example items were, “In this class, my classmates and I actively work together to complete assignments”, and “In this class, my classmates and I actively work together to help each other understand the material.”

- **MSLQ Self-efficacy.** This subscale assessed students’ confidence in their ability to learn class information. There were a total of 8 items used. Example items were, “I am confident I can understand the basic concepts taught in this course”, “I am confident I can do an excellent job on the assignments and tests in this course”, and “I am certain I can master the skills being taught in this course.”

- **Course Grade.** Students’ course grades were measured on a 4-point grading system. The highest grade was an A+ (4.333) and the lowest grade was no credit (0.000).

**ANALYSIS**

For each student, a collaborative learning subscale score was obtained by calculating a mean score from the five SPOCK items; a self-efficacy subscale score was obtained by calculating a mean score from the eight MSLQ items.

The subscale scores for collaborative learning and self-efficacy as well as scores for course grade were converted to z-scores to remove group differences but preserve within-group position, which corrected for contextual differences between the different engineering courses. Descriptive statistics for all variables (see Table 1) were computed and analyzed, and a bivariate correlation matrix was constructed to examine the relationship between the variables.

| TABLE 1 | DESCRIPTIVE STATISTICS FOR ALL VARIABLES OF INTEREST |
|------------------|------------------|------------------|------------------|------------------|
| 1. Collaborative Learning (SPOCK) | Min | Max | M | SD |
| 2. Self-Efficacy (MSLQ) | -2.605 | 1.752 | -0.013 | 0.980 |
| 3. Course Grade | -2.696 | 1.815 | -0.041 | 0.952 |

Multiple regression analyses were then used to analyze the predictive power of collaborative learning on course grade over and above self-efficacy.

**RESULTS**

Descriptive statistics for variables are displayed in Table 1. Pearson product-moment correlation coefficients were computed among the three variables to examine the relationships between them. The results of the correlation analyses presented in Table 2 indicated significant positive relationships between collaborative learning and course grade, and self-efficacy and course grade. Also, the correlation between collaborative learning and self-efficacy was positively significant.

| TABLE 2 | CORRELATIONS AMONG ALL VARIABLES OF INTEREST |
|------------------|------------------|------------------|------------------|
| 1. Collaborative Learning (SPOCK) | - | - | - |
| 2. Self-Efficacy (MSLQ) | .20* | - | - |
| 3. Course Grade | .29** | .44** | - |

Regression analyses were then conducted to evaluate whether perception of collaborative learning predicted course grade over and above self-efficacy. The regression results are shown in Table 3.

First, a bivariate regression analysis was conducted to evaluate the prediction of course grade from self-efficacy. The results of this analysis showed that self-efficacy accounted for a significant amount of variance in the course grade, \( R^2 = .19, F (1, 148) = 34.84, p < .01 \), indicating that the two variables were linearly related and that students who reported higher levels of self-efficacy for the course tended to have higher achievement.

A multiple regression analysis was then conducted to evaluate how well the students’ perceptions of collaborative learning and self-efficacy predicted their course grade. The linear combination of self-efficacy and perception of collaboration was significantly related to course grade, \( R^2 = .23, \) adjusted \( R^2 = .22, F (2, 147) = 22.42, p < .01 \). Moreover, results indicated that perceptions of collaborative learning accounted for a significant proportion of variance in the course grade after controlling for the effects of self-efficacy, \( R^2 \Delta = .04, F (1, 147) = 8.293, p < .01 \). An additional 4% of the variance in course grade was accounted for by including perception of collaboration and self-efficacy as predictors versus only self-efficacy. These results indicated that students with similar levels of self-efficacy were more likely
to have higher course grades if they engaged in collaborative learning interactions with their classmates.

**TABLE 3**

| Model / Model Variables | Model $R^2$ | Adj $R^2$ | B (SE B) | $\beta$ | Part $^2$
|-------------------------|-------------|------------|----------|--------|-------
| **1. Bivariate regression model**<br>Intercept | .19* | .19* | -0.03 (0.07) |  |  |
| Self-Efficacy |  |  | .45 (0.08) | .43* |  |
| **2. Multiple regression model**<br>Intercept | .23* | .22* | -0.03 (0.07) |  |  |
| Self-Efficacy |  |  | .41 (0.08) | .39* | .15 |
| Collaborative Learning |  |  | -0.21 (0.07) | .21* | .04 |

Note. $N = 150; * p < .01.$

**DISCUSSION**

The results of the current study suggested that collaborative learning was a predictor of students’ academic achievement over and above self-efficacy in engineering courses. Students who engaged in collaborative learning had higher self-efficacy for learning the course content. However, regardless of their levels of self-efficacy, students who engaged in collaborative learning performed better in terms of grades than those who worked independently.

In regard to these findings, it is important to note that collaboration may not always need to be a highly structured, planned part of the curriculum. The survey questions used in our study [11] referred primarily to students’ perceptions of collaboration that occurred in a spontaneous or incidental manner – brief in-class peer discussion, study groups, conversations after class, and the like. Other studies also identify this informal type of collaboration as being beneficial to student learning in terms of achievement [19].

This means of collaboration may appeal to instructors who prefer a traditional lecture-based class format because they could emphasize elements in their lecture that encourage students’ interaction, but wouldn’t necessarily need to alter the class structure. Potentially students could benefit from brief in-class discussion and sharing, or being encouraged to work with others on difficult problems outside of class.

Additionally, students’ perceived value of informal collaboration as a strategy to improve learning may influence their help-seeking behaviors and perceptions of their own ability. The key behavioral patterns of learned helplessness observed by Guzdial et al. [4] are passiveness in help-seeking and little consideration for their peers as helpers. Collaboration as a help-seeking or help-giving behavior may be viewed by students as more valuable to knowledge construction than structured group work, where the many complexities of group dynamics often take precedence over knowledge building activities and can yield negative self-perceptions. Informal collaboration may be more beneficial in the long run simply because students initiate it and thus students’ feel more empowered to influence their own learning. However, more research is necessary to examine the relationship between incidental collaboration, help-seeking, and learned helplessness.

As earlier noted however, students’ willingness to collaborate with their peers is decreased when working on problems that have been framed as a competitive pursuit toward a single answer. Even though faculty claim that one-answer problems are not the norm in engineering education, student perceptions have been found to differ [4]. Additional challenges are presented for engineering faculty to create opportunities for collaboration in the classroom by providing opportunities for complex problem solving that require cooperative, divergent thinking. While many aspects of engineering practice remain an exact science, we argue current engineering educational applications require a post-positivist view of knowledge representation and learning that takes into account individual differences and the social construction of understanding.

Our results suggested that in the engineering learning setting, students’ self-reported collaborative learning was significantly positively correlated with their academic achievement. Engineering faculty may show resistance to or confusion about the effectiveness of collaborative learning to improve student achievement [2, 4]. Yet, our results indicate that students who engage in collaboration with peers achieved at higher levels than those who did not. In a competitive academic environment such as engineering, students’ academic achievement is highly valued. However, information is relatively sparse regarding the process through which some students learn better than others. Our current study suggests that collaborative learning should be viewed as an important strategy to foster engineering students’ academic achievement.

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